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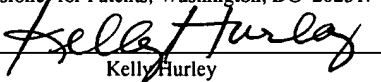
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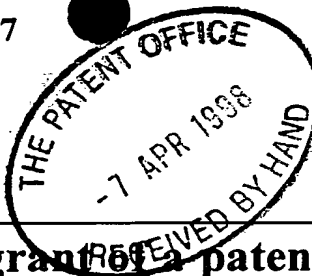
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Bristol  
BS8 1TH

Patents ADP number (*if you know it*)  
If the applicant is a corporate body, give the country/state of its incorporation

United Kingdom  
798181001

4. Title of the invention  
AN AQUEOUS SOLUTION

5. Full name of your agent (*if you have one*)

Haseltine Lake & Co.

"Address for service" in the United Kingdom to which all correspondence should be sent (*including the postcode*)

Imperial House  
15-19 Kingsway  
London WC2B 6UD

Patents ADP number (*if you know it*)

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6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (*if you know it*) the or each application number

Country

Priority application number  
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7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application

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8. Is a statement of inventorship and of right to a grant of patent required in support of this request? (*Answer "Yes" if:*

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Request for preliminary examination and search (Patents Form 9/77) 1

Request for substantive examination (Patents Form 10/77) 0

Any other documents (please specify) 0

11. I/We request the grant of a patent on the basis of this application

Signature

*L.C. Sealy*

Date

6th April 1998

12. Name and daytime telephone number of person to contact in the United Kingdom

Dr. L.C. Sealy

[0117] 9260197

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DUPLICATE

-1-

# AN AQUEOUS SOLUTION

This invention relates to aqueous solutions for use in surgical procedures, and is particularly concerned with an ophthalmic irrigating solution useful  
5 for irrigating the human eye during surgery.

A description of the problems associated with surgical procedures, especially surgical procedures performed on the eye, and the historical development of tissue irrigating solutions may be found in  
10 EP-A-0076658.

The stated object of EP-A-0076658 is to provide a stable sterile ophthalmic irrigating solution which, in addition to correct electrolyte balance, provides factors necessary for continued metabolism in the  
15 endothelial cells, maintenance of the fluid transport pump system, and consequential maintenance of proper corneal thickness and clarity. This problem is stated to be achieved in EP-A-0076658 by providing a two-part solution system which includes a basic solution and an  
20 acidic solution which are individually stable and which, on mixing, form an ocular solution which contains the necessary factors to maintain endothelial cell integrity and corneal thickness during ocular surgery. The combined solution contains the necessary  
25 ions in a bicarbonate-phosphate buffer as well as oxidised glutathione and dextrose (d-glucose), the latter being present as an energy source.

There are problems associated with the solution system of EP-A-0076658. Firstly, such a system is  
30 relatively expensive because two separate solutions must be prepared and separately sterilised; this problem is not easy to overcome because certain of the ingredients of the system, particularly the oxidised glutathione and the glucose, are heat-labile and cannot  
35 therefore be sterilised by an autoclaving procedure as required by various regulatory authorities for

solutions exceeding about 500ml in volume which are to be used in surgical procedures. As a consequence, the two-part system of EP-A-0076658 is prepared, in practice, such that the non-labile components are present in the solution which contains the majority of the fluid which will form the final ocular solution, which is then bottled and autoclaved. The labile components are contained in the other solution of relatively small volume (below the threshold above which autoclaving is required) which may be sterilised by a filtration technique.

A second problem with the solution system of EP-A-0076658 is that its two-part nature can potentially lead to errors in forming the final ocular solution, a procedure which is normally conducted in a hospital.

HEPES has been proposed, in the 1980 article "Intraocular irrigating and replacement fluid", M.V. Graham et al, Trans. Ophthal. Soc. U.K. (1980) 100, p282-285, as a buffer for an intraocular irrigating solution. However, the 1983 article, "A Comparison of HEPES and Bicarbonate Buffered Intraocular Irrigating Solutions: Effects on Endothelial Function in Human and Rabbit Corneas", by Dayle H. Geroski et al, J. Toxicol - Cut & Ocular Toxicol 1(4), 299-309, (1982-83) concludes that HEPES is toxic to endothelial Na<sup>+</sup>K<sup>+</sup>ATPase and questions the prudence of using HEPES buffer in intraocular irrigating solutions.

It would be an advantage to provide a stable ophthalmic irrigating solution as a single solution capable of being sterilised by autoclaving.

It has now been found that a solution which is effective as an ophthalmic irrigating solution can be formed which does not require the glutathione ingredient previously believed to be essential, but does include a specific buffer to ensure that the

proper pH is maintained prior to and during use.

Thus, according to a first aspect of the present invention there is provided an ocular irrigating solution for irrigating the eye during surgery comprising, a source of bicarbonate ions and a physiologically acceptable organic buffer which is an organic zwitterionic buffer having a buffering capacity within the range pH 6.8 to 8.0.

The organic buffer preferably maintains the solution at a pH in the range 7.2 to 7.8 to match the physiological pH of 7.4.

Highly preferred as the organic buffer are the zwitterionic amino acids, such as N-2-[hydroxyethyl]piperazine-N'-[2-ethanesulfonic acid], commonly referred to as HEPES, which has a pKa of 7.55 at 25°C. Other organic buffers in this family are N,N-bis[2-hydroxyethyl]-2-aminoethanesulfonic acid (BES), pKa=7.1; 3-[N-morpholino]propanesulfonic acid (MOPS), pKa=7.2 at 25°C; N-tris[hydroxymethyl]methyl-2-aminoethanesulfonic acid (TES), pKa=7.4 at 25°C; N-[2-hydroxyethyl]-piperazine-N'-[3-propanesulfonic acid] (EPPS), pKa=8.0 at 25°C; N-tris[hydroxymethyl]methyl-glycine (TRICINE), pKa=8.1 at 25°C.

The organic buffer should be present in the solution in an amount sufficient to buffer the solution over the duration of the surgical procedure. In practice, this means that the concentration of the buffer should be about 10 to 50 mmol/l.

The bicarbonate source is normally sodium bicarbonate. The bicarbonate source is preferably present in the solution to give a bicarbonate concentration of about 10 to 50 mmol/l, preferably from 15 to 25 mmol/ml to maintain the fluid pump system in the endothelium of the eye.

The ocular irrigating solutions of the present invention are preferably free from glutathione, which

has previously been considered essential for effective performance.

Hitherto it has been considered essential for ocular irrigating solutions to contain an energy source which is purportedly required as a substrate for the various metabolic pathways taking place in the cornea. It has now surprisingly been discovered that ocular irrigating solutions which are free from an energy source (such as glucose) are capable of supporting endothelial function and maintaining corneal thickness as well as solutions containing the energy source. Thus, irrigation solutions of the invention need not contain an energy source. This is of particular significance so far as glucose is concerned which tends to degrade at physiological pH over extended time periods. Therefore, preferred ocular irrigation solutions of the present invention do not contain glucose, or any other energy source which tends to degrade at physiological pH over extended time periods. If an energy source is to be present in an irrigation solution of the invention, a typical concentration is 2-10 mmol/l.

The solution of the invention preferably also contains other electrolytes necessary to maintain physiological function, such as  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ , and  $\text{Cl}^-$ , but not  $\text{Mg}^{2+}$ , which can lead to the formation of magnesium precipitates in some circumstances. These should be present at concentrations which will permit continued cellular integrity and metabolism. Typically, these electrolytes are present in the following concentrations:

	$\text{Na}^+$	130 - 180 mmol/l
	$\text{K}^+$	3 - 10 mmol/l
	$\text{Ca}^{2+}$	up to 5 mmol/l
35	$\text{Cl}^-$	130 - 210 mmol/l

Preferably the concentration of  $\text{Ca}^{2+}$  is at least  
0.05 mmol/l, and preferably no more than 0.1 mmol/l.

Moreover, the osmolality should be between  
approximately 250 - 350 mosmol/kg, preferably 290 - 320  
5 mosmol/kg, to maintain osmotic stability of the cells.

Also normally present in the solution will be a  
source of phosphate ions, although primarily not for  
buffering purposes, as in EP-A-00766598, but for normal  
physiological function. The approximate concentration  
10 of phosphate in the solution is normally about 1  
mmol/l.

The solution of the invention may be prepared by  
mixing the components together in aqueous solution, in  
the desired proportions. It may then be bottled and  
15 autoclaved in the normal manner.

One advantage of the invention is that it may be  
autoclaved without any deleterious effect. For this  
reason, components which would degrade to a significant  
extent under the chosen autoclave conditions should be  
20 excluded or reduced in amount to a point at which  
degradation is minimal. Typical autoclave conditions  
are 121°C for 15 minutes or 134°C for 3 min.

The ocular solution of the invention should  
preferably be free from nutrients of the type normally  
25 present in tissue culture media, namely: amino acids,  
vitamins, hormones, proteins, growth factors, lipids,  
nucleosides, minerals.

The solution of the invention may be used in a  
method of surgery performed on the human eye to replace  
30 fluid loss during the operation and to maintain corneal  
function. Thus according to another aspect of the  
invention, there is provided an aqueous solution,  
comprising a source of bicarbonate ions and a  
physiologically acceptable organic buffer which is an  
35 organic zwitterionic buffer having a buffering capacity  
within the range pH 6.8 to 8.0, for use in a surgical

method, preferably a surgical method performed on the eye.

The invention will now be illustrated by reference to the following Example and drawings in which:

5        Figure 1A shows the change in corneal thickness during assessment perfusion following 90 minutes exposure to the "UB-M2" solution in accordance with the invention and "BSS Plus";

10       Figure 1B shows the change in corneal thickness during perfusion with a solution in accordance with the invention "UB-M2" solution and with "BSS Plus".

#### Example 1

15       A prior art irrigating solution and an irrigating solution in accordance with the invention were tested in a masked laboratory experiment to evaluate their effectiveness. BSS Plus (which is in accordance with EP-A-0076658) was obtained as a two part system and made up as directed. The composition of these  
20       solutions along with those of aqueous humour and BSS are shown in Table 1.

Table 1

		Aqueous humour	BSS	BSS Plus	Invention
	Na <sup>+</sup> (mM)	162.9	144.0	160.0	137.2
	K <sup>+</sup> (mM)	2.2-3.9	10.0	5.0	5.4
5	Ca <sup>2+</sup> (mM)	1.8	4.3	1.0	0.075
	Mg <sup>2+</sup> (mM)	1.1	3.2	1.0	-
	Cl <sup>-</sup> (mM)	131.6	127.2	130.0	121.2
	HCO <sub>3</sub> <sup>-</sup> (mM)	20.2	-	25.0	20.0
	HPO <sub>4</sub> <sup>2-</sup> (mM)	0.6	-	3.0	0.8
10	SO <sub>4</sub> <sup>2-</sup> (mM)	-	-	-	-
	Acetate (mM)	-	28.6	-	-
	Citrate (mM)	-	5.8	-	-
	Lactate (mM)	2.5-4.5	-	-	-
	Glucose (mM)	2.7-3.7	-	5.0	-
15	Glutathione	1.9 $\mu$ M	-	0.3 mM	-
	HEPES (mM)	-	-	-	20.0
	Osmolality (mosmol/kg)	304	302	305	320
	pH (20°C)	7.4	7.3	7.4	7.4
20	Corneas obtained from New Zealand White rabbits (3-4 kg) after an intravenous overdose of pentobarbitone sodium were secured on support rings and perfused as described in J. Physiol 1972; 221: 29-41, 25 "The metabolic basis to the fluid pump in the cornea", Dikstein S. and Maurice DM. The paired corneas from each rabbit were randomly allocated, one to BSS Plus and one to the invention. The allocation was unknown to the person performing the experiment. The 30 epithelial surface was covered with silicone oil to prevent changes in corneal thickness owing to evaporation.				
	The endothelial surface was perfused at 2.5 ml/h, a pressure of 15 cm H <sub>2</sub> O and 35°C. During the first 90 35 minutes of perfusion, corneas were exposed to the intraocular irrigation solution. This was followed by a further 6 hours of perfusion during which endothelial				

function was assessed.

Corneal thickness was measured with an ultrasonic pachymeter (DGH Technologies, Inc), every 30 minutes. The silicone oil was removed briefly to allow the  
5 measurements to be made. Each measurement was the mean of readings taken at four different sites of the central cornea.

Changes in corneal thickness during perfusion for 90 minutes with the irrigation solutions are shown in  
10 Figure 1A.

Corneal hydration and, thus, thickness are controlled by the endothelium through a pump leak mechanism. Removal of bicarbonate ions from the perfusate suppresses endothelial pump function and  
15 causes corneal swelling, although inhibition of the pump is not complete unless CO<sub>2</sub> is also removed from the perfusate. Pump function can be restored and the swelling reversed by returning bicarbonate to the perfusate.

20 After the 90 minute perfusion with one of the irrigation solutions, endothelial function was, therefore, assessed during a further 6 hours of perfusion with Tissue Culture Medium 199 (TC199). The first 2 hours of perfusion were with TC199 with Earle's  
25 salts (Sigma, M3769). This solution contained sodium bicarbonate (26 mmol/l), and should have supported endothelial pump function. Two hours of perfusion with TC199 with Hanks' salts (Sigma, M3274) then followed. This solution did not contain bicarbonate ions and,  
30 thus, should have caused corneal swelling, although the solution was not CO<sub>2</sub> free. For the final 2 hours, perfusion with TC199 Earle's was restored and, providing that the endothelium was undamaged, corneas should have thinned. Neither of the TC199 solutions  
35 contained phenol red, and their measured osmolalities (Roebeling osmometer) were 290 and 288 mosmol/kg,



respectively, for TC199 with Earle's salts and TC199 with Hanks' salts.

Rates of change in corneal thickness both during perfusion with the irrigation solutions and during the three parts of the assessment perfusion were determined by regression analysis. Comparisons were made between groups by t-tests at the 5% level of significance. The results obtained are shown in Table 2 and are also illustrated graphically in Figure 1A.

Table 2

Irrigation solution <sup>a</sup>	Initial 90 min exposure to irrigation solution	Rate of change in corneal thickness ( $\mu\text{m}/\text{h}$ ) <sup>b</sup>		
		TC199 Earle's 0-2 h	TC199 Hank's <sup>c</sup> 2-4 h	TC199 Earle's 4-6 h
BSS Plus	-5.1(4.3)	+0.02(4.2)	+16.1(1.9)	-13.1(5.3)
Invention	-8.4(3.5)	+1.4(4.7)	+17.7(2.0)	-13.4(3.7)

<sup>a</sup>Corneas were perfused for 90 minutes with an irrigation solution before the assessment perfusion with TC199.

<sup>b</sup>Regression coefficient (SD), n=4: + indicates swelling, - indicates thinning.

<sup>c</sup>TC199 Hanks' does not contain  $\text{HCO}_3^-$ .

There were no differences at the 5% level of significance in rates of change in thickness between corneas exposed to BSS Plus and those exposed to the irrigating solution in accordance with the invention at any stage of the perfusion.

### Example 2

An ocular irrigating solution in accordance with the invention was made up as in Example 1.

Corneas were dissected, mounted on support rings and perfused as in Example 1 except that the corneas were perfused continuously for a period of 7.5 hours with either BSS Plus or the invention. Paired corneas, from a single rabbit, were perfused, one with BSS Plus and the other with the invention. The allocation of

corneas to each solution was randomized and masked from  
the person performing the perfusion. Regression  
analysis showed no overall change (at the 5% level of  
significance) in thickness during the course of the  
5 perfusion nor was corneal thickness influenced by the  
type of irrigation solution (see Figure 1B).

In conclusion, Examples 1 and 2 demonstrate that  
the invention supports endothelial function at least as  
well as BSS Plus, despite the absence of components,  
10 such as glucose and glutathione, that are considered  
essential constituents of BSS Plus.

CLAIMS

1. An ocular irrigating solution for irrigating  
the eye during surgery comprising, a source of  
bicarbonate ions and a physiologically acceptable  
5 organic buffer which is an organic zwitterionic buffer  
having a buffering capacity within the range pH 6.8 to  
8.0.
2. An ocular irrigating solution according to  
claim 1, wherein the organic buffer maintains the  
10 solution at a pH in the range 7.2 to 7.8.
3. An ocular irrigating solution according to  
claim 1 or 2, wherein the organic buffer is a  
zwitterionic amino acid.
4. An ocular irrigating solution according to  
15 claim 3, wherein the organic buffer is N-2-  
[hydroxyethyl]piperazine-N'-[2-ethanesulfonic acid].
5. An ocular irrigating solution according to  
any preceding claim, wherein the concentration of the  
buffer is from 10 to 50 mmol/l.
- 20 6. An ocular irrigating solution according to  
any preceding claim, wherein the bicarbonate source is  
sodium bicarbonate.
7. An ocular irrigating solution according to  
claim 6, wherein the bicarbonate source is preferably  
25 present in the solution to give a bicarbonate  
concentration of about 10 to 50 mmol/l.
8. An ocular irrigating solution according to  
any preceding claim which does not contain glucose, or  
any other energy source which tends to degrade at  
30 physiological pH over extended time periods.
9. An ocular irrigating solution according to  
any preceding claim having been sterilised by an  
autoclaving procedure.
10. An ocular irrigating solution according to  
35 claim 1, for use in a surgical method performed on the  
eye.

11. A method of surgery performed on the human  
eye in which an ocular irrigating solution according to  
any one of claims 1 to 9 is employed to replace fluid  
loss during the operation and to maintain corneal  
5 function.

12. An ocular irrigating solution substantially  
as hereinbefore described, with reference to the  
accompanying examples.

ABSTRACT

AN AQUEOUS SOLUTION

There is disclosed an ocular irrigating solution for irrigating the eye during surgery comprising, a  
5 source of bicarbonate ions and a physiologically acceptable organic buffer which is an organic zwitterionic buffer having a buffering capacity within the range pH 6.8 to 8.0.

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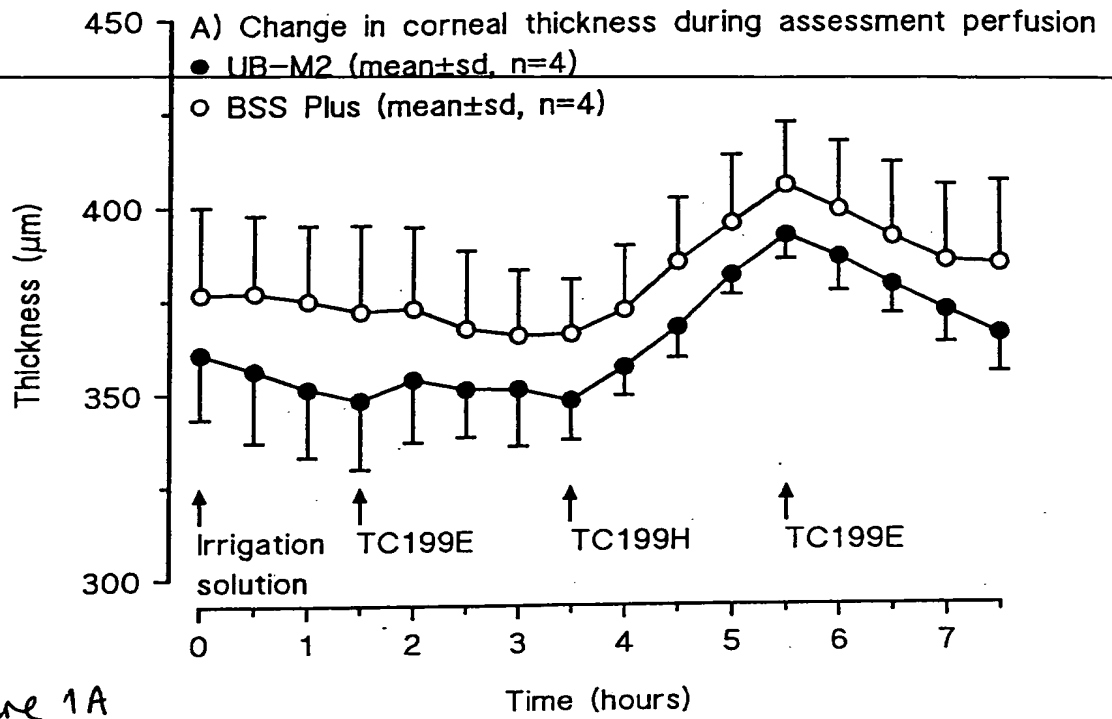


Figure 1A

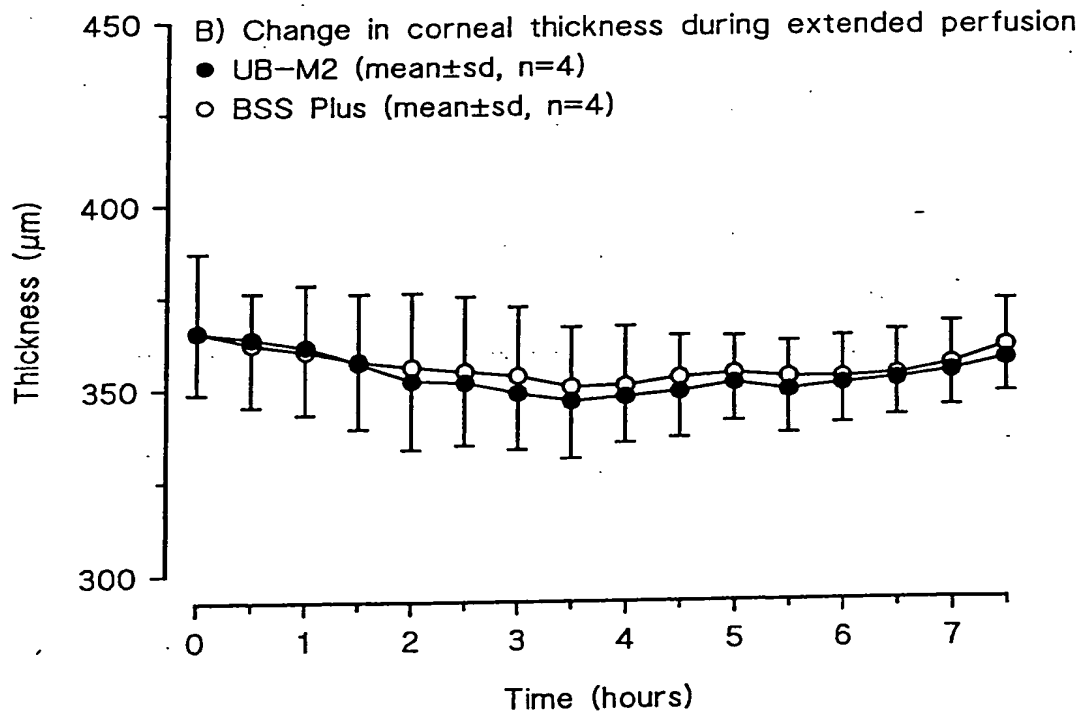


Figure 1B

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